Shelterbelt Establishment and Growth at a Windswept Wyoming Rangeland Site

David L. Sturges

Research Paper RM-243
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U.S. Department of Agriculture

USDA Forest Service
Research Paper RM-243

February 1983

Shelterbelt Establishment and Growth at a Windswept Wyoming Rangeland Site

David L. Sturges, Research Forester
Rocky Mountain Forest and Range Experiment Station[1]

Abstract

Survival and growth of six shelterbelt tree and shrub species and three rangeland shrubs were evaluated for 5 years at a planting site adjacent to Interstate-80 in southcentral Wyoming. Depredation by rodents at the rangeland site limited establishment and growth of some species more severely than did the harsh climate.

[1]*Headquarters is in Fort Collins, in cooperation with Colorado State University; research reported here was conducted at the Station's Research Work Unit at Laramie, in cooperation with the University of Wyoming. Research was supported in part by the Wyoming Highway Department.*

Shelterbelt Establishment and Growth at a Windswept Wyoming Rangeland Site

David L. Sturges

Management Implications

This study indicates that shelterbelt tree and shrub species do not become large enough to serve as effective snow control agents for a number of years after planting. Three conifer species, initially 0.10 to 0.15 m tall, were 0.4 to 0.5 m tall after 5 years. Colorado blue spruce and ponderosa pine appeared equally well adapted to the harsh environmental conditions at the study site.

Russian olive was the most promising deciduous species for shelterbelt use, based on this study. It had a densely branched growth form, and lateral crown spread was approximately equal to plant height. Initial survival of Russian olive was low, but probably can be enhanced by using as parent stock plants that have shown adaptability to severe environmental stresses. Siberian peashrub is described as a vigorous and densely branched shrub when grown in shelterbelts on the High Plains of eastern Wyoming (Howard 1964, Edmondson 1951). However, at the study site it had a spindly growth form and should be planted closer than the 2.4-m spacing used in this study. The average height of Siberian peashrub exceeded all other species after 5 years, but most of this growth was in the first 3 years of the study.

White rabbitbrush was the only rangeland shrub that showed promise as a shelterbelt species. Its initial survival was low, which may be an artifact of the manner in which seedlings were handled prior to planting. Additional testing is required to improve establishment methods. Initial growth rates of Colorado and Nevada selections of basin big sagebrush were extremely rapid. However, a lack of winter hardiness prohibits use of this sagebrush subspecies where environmental conditions are similar to those at the study site.

The presence of an upwind snow fence to ameliorate wind speed did not influence either establishment success or the growth rate of conifer and deciduous shelterbelt species. Additional trials would be useful to verify this conclusion, because of limitations imposed by the study site. Such trials should be conducted where plantings can be made (a) outside of the area influenced by wind flow around the ends of a snow fence, and (b) at sufficient distance downwind from a snow fence to be free of the drift cast by the fence. Drifts cast by a Wyoming snow fence extend downwind for a distance of 29.5 times fence height when the fence is filled with snow, while drifts cast by the vertical-slat, "Canadian" snow fence extend downwind about 26.5 times fence height (Tabler 1980).

The study conclusively demonstrates that wildlife depredation can be as severe a problem to shelterbelts planted on rangelands as severe climatic conditions. Siberian elm and oldman wormwood are not suitable species if white-tailed jackrabbits and Richardson's ground squirrels, respectively, are present. Different mammal species at another shelterbelt location might prohibit use of some tree or shrub species that were acceptable in this study. Indeed, woody-species plantings on two mine spoils north of Interstate-80 in southcentral Wyoming were also subjected to severe wildlife depredation (Howard et al. 1979).

An inventory of mammals indigenous to a prospective shelterbelt location should precede establishment of the planting, and plant species attractive to wildlife should not be planted. Various types of repellents and shields are available to protect plants from wildlife. Use of these agents may alleviate depredation during establishment. However, shelterbelts adjacent to rangeland will be subjected to wildlife depredation over the life of the planting. This fact must be recognized and accounted for in project design.

Introduction

Scientifically designed snow fence systems along Interstate-80 in southcentral Wyoming have improved the safety of motorists during periods of blowing snow and have reduced winter maintenance expenditures (Tabler and Furnish 1982). Fence systems consist of wooden structures 3.8 m in height, with lesser use of barriers 3.2 m or 2.6 m tall. Multiple rows of fences are necessary in locations with high snow transport. While the value and efficiency of snow fences in trapping blowing snow is unquestionable, questions have arisen over whether shelterbelts might also serve the same snow control function. Shelterbelts also may be less of an aesthetic intrusion on the landscape than are wooden snow fences.

The ability of shelterbelts to reduce windspeed and enhance the beauty of farmsteads on the edge of the Great Plains in eastern Wyoming (where elevations range from approximately 1,250 m to 1,850 m) is well accepted. Technical information exists concerning the suitability of various tree and shrub species as well as proven methods to establish and care for the planting (Howard 1982, Johnson and Anderson 1980, Cook 1978, Howard 1964, Edmondson 1951). The climate further west in the state on the high plains traversed by Interstate-80 is too severe for intensive agriculture, and the land retains native shortgrass or sagebrush vegeta-

tion. Information is lacking about the ability of shelterbelt species to survive and grow under the severe environmental conditions that exist along the Interstate where elevations reach 2,400 m. Such information though, is essential for assessing the possible use of shelterbelts for highway snow control.

The current study was initiated in cooperation with the Wyoming State Highway Department to determine (a) if shelterbelt species can be established in windswept locations typical of high-elevation rangeland traversed by Interstate-80 in southcentral Wyoming, (b) if placement of the planting downwind of a snow fence to take advantage of the reduction in windspeed enhances plant survival and growth, and (c) the survival and growth characteristics of species for a 5-year period after planting.

An existing snow fence system on the south side of Interstate-80 about 8 km east of the town of Elk Mountain was utilized as a study site (fig. 1). The site is in rolling terrain at a 2,300-m elevation and consists of a lead fence 3.2 m tall and downwind fence 3.8 m tall. Native vegetation was dominated by Wyoming big sagebrush (*Artemisia tridentata* sub. *wyomingensis*) about 10 cm tall. Soil belonged to the Lithic Cryoboroll great soil subgroup and developed in place from outwash material originating in the nearby Medicine Bow Mountains. The solum was 30 cm thick with a sandy loam texture in A and B horizons.

The planting site is 35 by 152 m and fenced with woven wire on three sides. The 3.8-m snow fence on the downwind boundary enclosed the remaining side to exclude grazing by livestock and big game. Windspeeds over about 60% of the site were ameliorated by the 3.2-m upwind snow fence; the remainder of the site was fully exposed to ambient winds. The site was plowed to kill all native vegetation at study initiation in 1975 and sprayed with a herbicide in 1976 to control weed invasion. Weeds around plants were subsequently controlled mechanically one time so that competition from native vegetation had little, if any, effect on study results. The planting remained insect-free throughout the study.

Figure 1.—The shelterbelt study site was on the windward side of the 3.8-m snow fence nearest Interstate-80 at the bottom of the photo. Windspeed over 60% of the study site was reduced by an upwind snow fence 3.2 m tall.

Three conifer species, Colorado blue spruce (*Picea pungens*), ponderosa pine (*Pinus ponderosa*), and white fir (*Abies concolor*), and three deciduous species, Russian olive (*Elaeagnus angustifolia*), Siberian elm (*Ulmus pumila*), and Siberian peashrub (*Caragana arborescens*), were evaluated. These species are considered drought resistant and adapted for use within the Central Great Plains region of Wyoming (Howard 1982). The stock was obtained from the Fort Collins nursery of the Colorado State Forest Service, except for Siberian peashrub, which was dug from an existing shelterbelt near Cheyenne, Wyo. The planting was made June 27 and 28, 1975. Plants were placed in holes 61 cm in diameter in which soil was previously loosened to a 61-cm depth with an auger.

Conifers were 10-15 cm tall when planted and came from container-grown stock, while deciduous species were planted as bare-root stock. Bare-root stock was held in cold storage for about 6 weeks after digging until the field site had been prepared. Two slow-release fertilizer tablets (20% nitrogen, 10% phosphorus, 5% potassium) that weighed about 20 g each were placed in soil adjacent to each plant at the time of planting. The plants were watered in the summer months during 1975 and 1976 at irregular intervals so that soil moisture stress was not a survival factor. Most individuals that died in the first year of study were replaced in June 1976 with new stock obtained from the same source as that planted in 1975. Consequently, study measurements for the 1976 planting ended 1 year later than for the 1975 planting to permit expressing all data in terms of years after planting.

Each species was planted in a single row 122 m long oriented perpendicular to the southwesterly prevailing winds, except for Siberian peashrub, which was planted in two rows (fig. 2). About 60% of each row was within that portion of the study site protected by the upwind snow fence. The remainder of each row was exposed to prevailing winds. The location of each row of plants with respect to the snow fence 3.2 m tall on the upwind side of the planting site is shown on figure 2; the distance between plants is also shown on the figure.

In addition to the six conventional shelterbelt tree and shrub species, two common western shrubs and a sagebrush introduced from Europe were evaluated. These were chosen because of rapid growth characteristics exhibited at the Ephraim, Utah, shrub garden maintained by the Intermountain Forest and Range Experiment Station. Two sources of basin big sagebrush (*A. t. sub. tridentata*) collected in Colorado and Nevada, white rabbitbrush (*Chrysothamnus nauseous sub. albicaulis*), and oldman wormwood (*A. abrotanum*), were planted. Oldman wormwood is a deciduous, European shrub that grows from 1.0 m to 1.5 m tall (Plummer 1974). Because of its ability to withstand drought, oldman wormwood is used as an ornamental and to vegetate disturbed sites, such as roadside cut or fill slopes.

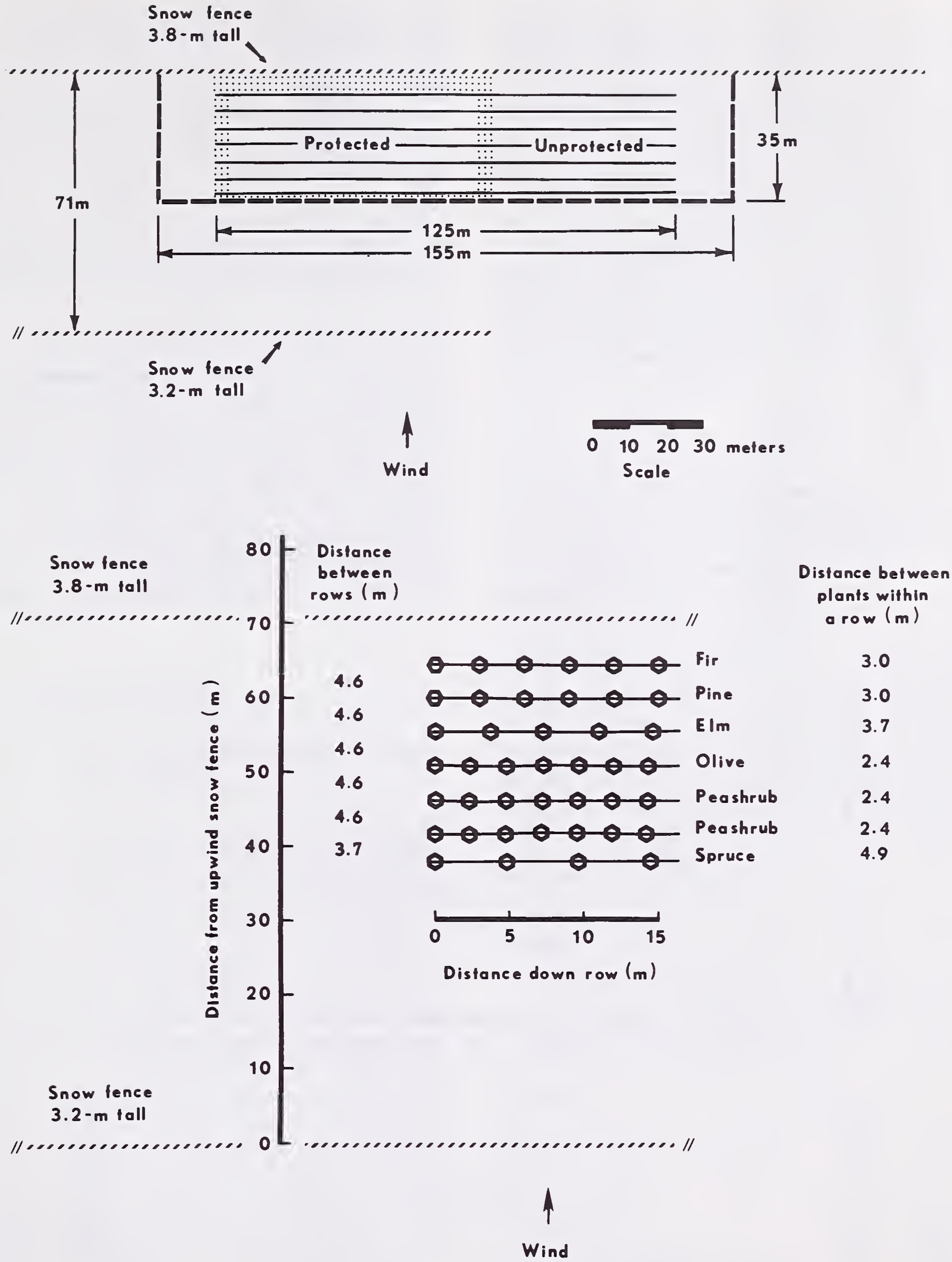

Figure 2.—Location of the upwind snow fence 3.2 m tall and the 3.8-m snow fence with respect to the planting site is shown on the top half of the figure. The location of each row of species at the study site, spacing between rows of plants, and spacing between plants within a row, is shown on the bottom half of the figure.

Big sagebrush and white rabbitbrush seedlings were dug at the Ephraim shrub garden May 11, 1976. Rooted and unrooted oldman wormwood cuttings were obtained from stock at the shrub garden, and all species were planted 2 or 3 days later at the shelterbelt site. Rangeland shrubs were placed 0.5 m on either side of the rows of Colorado blue spruce and ponderosa pine. Individuals of the three rangeland shrubs were planted sequentially at 0.8 m intervals until 28 plants of each species had been placed on either side of a conifer row. Rangeland shrub rows were 63.3 m long. Rooted oldman cuttings were placed adjacent to the Colorado blue spruce row, and unrooted cuttings were placed adjacent to the ponderosa pine row. Half of the plants of

the Colorado and Nevada selections of big sagebrush were placed along the Colorado blue spruce row, and half were placed along the ponderosa pine row. The configuration of the rangeland shrub planting did not allow the influence of snow fence protection upon plant establishment and growth to be evaluated.

Plant survival was determined in the spring as growth commenced (early June) and in the fall (early October) at the close of the growing season. Beginning in 1978, plant height was measured in the fall, and permanently marked plants of each species were photographed. The cross-sectional area and density of snow in the drift cast by the upwind snow fence were measured in March at the time of maximum accumulation.

Climate

Temperature and precipitation records collected in Elk Mountain at a National Oceanic and Atmospheric Administration (NOAA) co-operator station are available for the study period. Summer precipitation was measured at the shelterbelt site in a storage gage from 1977 to 1979 (after supplemental watering was discontinued). The orifice of the gage was located at ground level to minimize the influence of wind on gage catch. In 1976, wind speed was monitored at a 2-m height 12.6 km northwest of the planting site. Average monthly wind speeds measured at this gage are believed representative of values existing at the study site.

The shelterbelt site is typical of high plateau rangeland in Wyoming. Long-term annual precipitation at Elk Mountain is 32.7 cm, while the 5-year average during the study was 33.1 cm. Individual years ranged from 27.7 cm to 38.6 cm. Nearly a third of the yearly total, 12.7 cm per year for the 5-year study interval, fell during the snow drifting season, which extends from November 1, to March 31 (fig. 3). Summer precipitation measured at the shelterbelt site averaged 8.3 cm for the June-September interval (table 1).

The growing season extended from late in May, when deciduous species leafed out, until September, when freezing night-time temperatures and a shorter day-length caused leaf-fall. Night-time temperatures were consistently above freezing only in July and August. Minimum monthly air temperatures were below freez-

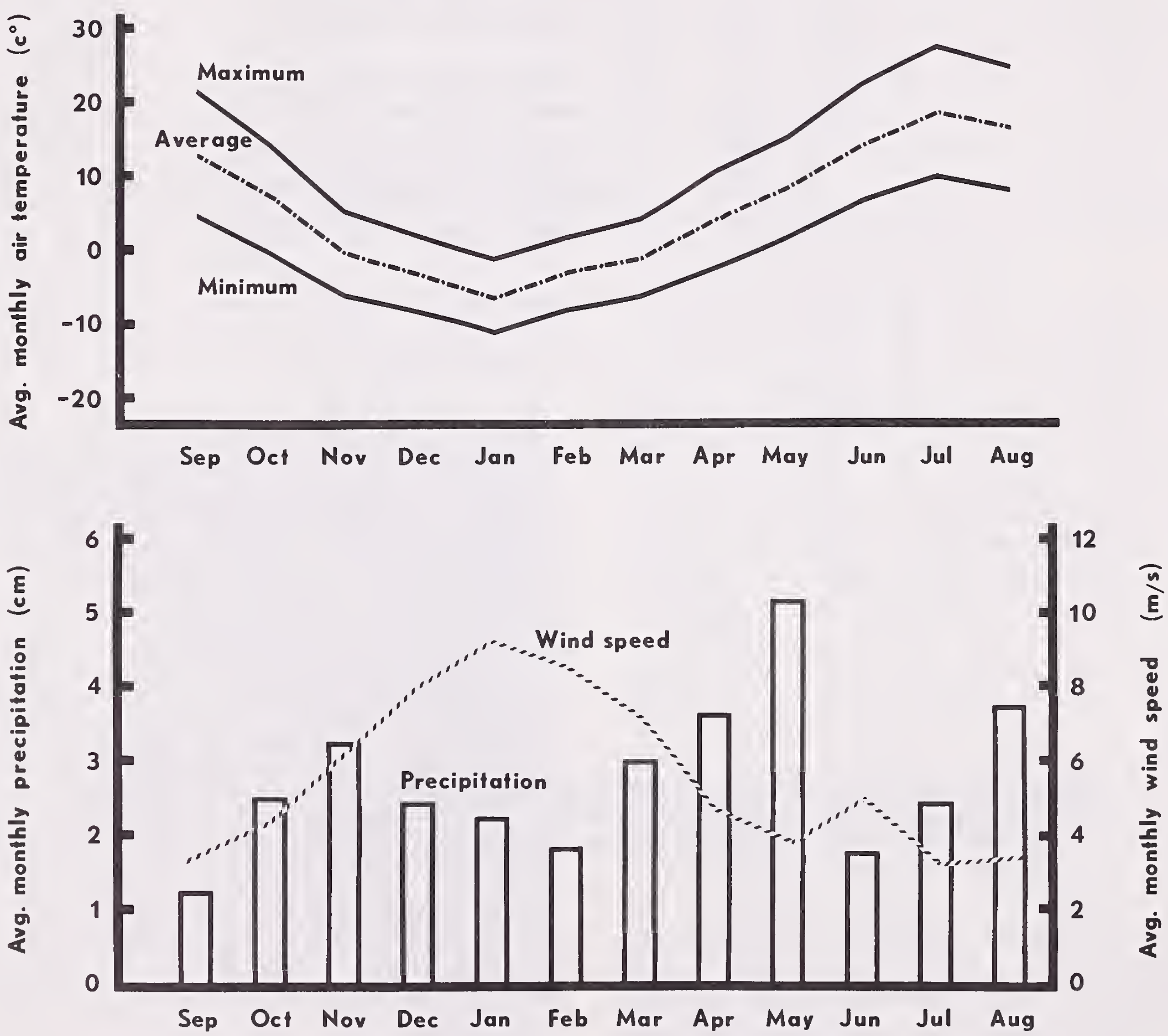

Figure 3.—Average monthly air temperature (top) and precipitation in the town of Elk Mountain and wind speeds during 1976 (bottom) as measured 12.6 km northwest of the study site.

Table 1. — Summer precipitation (cm) at the shelterbelt site

Year	Month				Total
	June	July	August	September	
1977	0.4	3.5	5.8	0.1	9.8
1978	1.1	1.3	3.8	Snow[a]	6.2
1979	1.4	1.3	5.2	.7	8.6
Average	1.0	2.0	4.9	.4	8.3

[a] *No measurement because of drifting snow; 2.5 cm precipitation was recorded during September at the National Oceanic and Atmospheric Administration co-operator station at Elk Mountain.*

ing from October through April (fig. 3). Monthly maximum air temperature peaked in July at 27° C. The cyclic yearly temperature and wind regimes are about 6 months out of phase (fig. 3). Windspeeds are at a maximum in midwinter and averaged more than 6 m/s throughout the 5-month drifting season. Monthly speeds were lowest in July and August with a value of about 3 m/s. Consequently, the simultaneous occurrence of low air temperature, frozen soil, and high wind speeds, created severe desiccation stresses on plants in winter months.

Results and Discussion

Effects of Wind Protection on Plant Establishment and Growth

The difference in survival of the six commonly planted shelterbelt species between locations protected and unprotected by the upwind snow fence was tested for significance by Chi Square. The difference in survival attributable to location was not significant (P = 0.05) 1 and 2 years after planting for any species.

The influence of fence protection on growth of the six shelterbelt species was evaluated after three, four, and five growing seasons, utilizing a *t*-test. The only significant height difference was for Siberian elm in the fifth growing season as elms growing in the unprotected location were taller than elms growing downwind of the snow fence. However, browsing by white-tailed jack rabbits (*Lepus townsendii*), not fence protection, was the primary factor influencing elm height at this time. The average height of elms progressively decreased after the third growing season because of jack rabbit depredation.

The configuration of snow fences at the study site complicated interpretation of study results in several ways, but should not have altered the basic outcome of the study. The rows of plants extended across the fenced/unfenced boundary. Wind is not always perpendicular to the fence which effects wind flow patterns and snow accumulation near the fence end. For example, overwinter snow accumulation is reduced for a distance of 12 times fence height from the end of a fence (Tabler 1980). Consequently, plants adjacent to tne fenced/unfenced boundary received somewhat less than full protection from the wind in the protected location and some protection from the wind in the unprotected location.

There was insufficient space between snow fences to locate the planting downwind of the equilibrium lee drift cast by the 3.2-m snow fence. At maximum storage capacity, the drift cast by a Wyoming snow fence extends 29.5H (H is vertical height of the fence) downwind from the fence and the deepest part of the drift is 6.7 H downwind from the fence (Tabler 1980). The planting was located between 12H and 20H downwind of the lead snow fence. The snow drift cast by the lead fence completely covered the planting at the close of the 1978-1979 and 1979-1980 winters, but failed to reach any part of the planting in the drought winters of 1976-1977 and 1980-1981 (fig. 4). Plants were in a uniform temperature regime at slightly below 0° C when covered by snow and were completely protected from wind. Approximately 250 cm of snow covered Colorado blue spruce in the two heavy winters; snow depth decreased across the planting site and the row of white fir was covered by 100 cm of snow. Some damage to Colorado blue spruce and Siberian peashrub did result from snow settlement.

The snow fence 3.8 m tall enclosing the downwind side of the study site reduced wind speeds immediately in front of the fence. The upwind drift could have extended beyond the row of Colorado blue spruce had this fence reached maximum storage capacity. However, the upwind drift was small even in heavy winters and barely reached the row of white fir which was closest to the fence. It is assumed then, that the presence of the 3.8-m fence had a negligible effect on wind speeds in the planting zone.

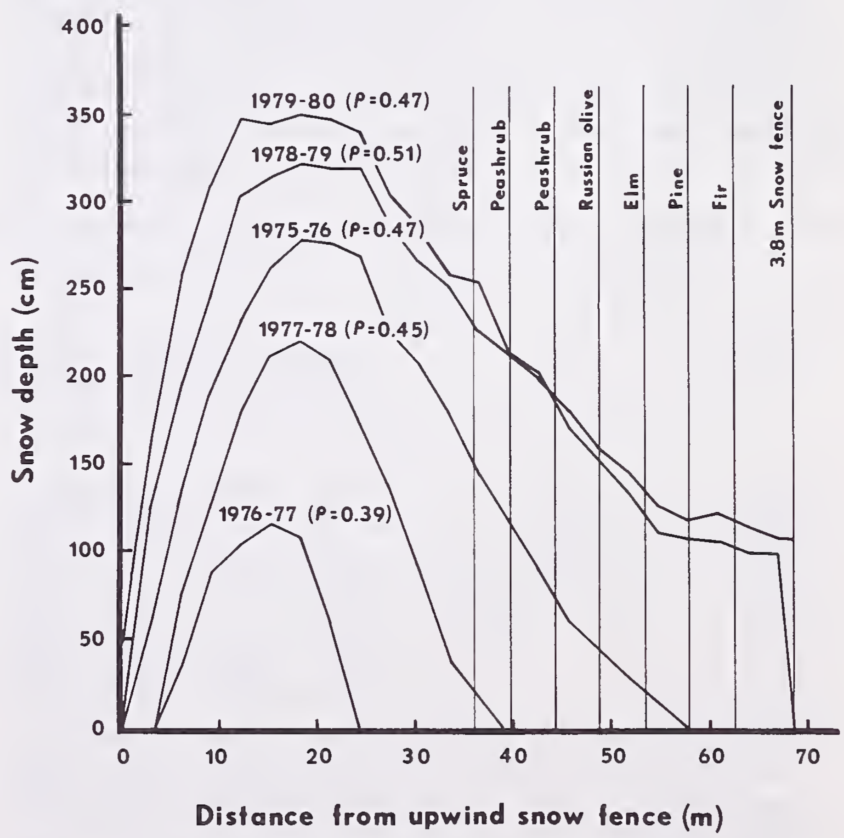

Figure 4.—Cross-sectional area and density (ρ) of snow in the drift cast by the 3.2-m upwind snow fence at maximum accumulation. The location of each species with respect to the upwind fence is indicated on the figure.

Species Survival and Growth

Because results of the protected-unprotected tests indicated that survival and growth of shelterbelt species were not affected by microclimatic changes induced by the upwind snow fence, data from the two locations were combined to determine a species average. Most mortality occurred within 2 years of planting (table 2). Colorado blue spruce and white fir survival at the end of 5 years was the highest of any species, 94% and 84%, respectively. Only 65% of the ponderosa pine planted in 1975 survived for 5 years, but 93% of the 15 pines planted 1976 survived, similar to the survival rate of other conifers. This suggests that either the stock or method of handling the stock in 1975 contributed to high ponderosa pine mortality.

The survival rate for Siberian elm 5 years after planting was 65%, the best of any deciduous species (table 2). Russian olive's mortality exceeded that of other deciduous species: only 16% of individual plants were alive after 5 years. However, all Russian olive mortality occurred within 2 years of planting and most plants died in the winter indicating a lack of winter-hardiness to conditions at the study site. Siberian peashrub losses also occurred in the first 2 years after planting.

Basin big sagebrush was the only species to experience appreciable mortality beyond the second year from environmental stresses (table 2). Both Colorado and Nevada selections of basin big sagebrush were poorly adapted to the severity of winter conditions at the planting site. Individual plants often suffered varying degrees of canopy dieback during the winter, even when they were not completely killed.

Shelterbelt plantings must not only establish readily, but also grow rapidly after establishment, to be a viable alternative to snow fences. Depredation by small mammals severely limited both establishment and growth of oldman wormwood and growth of Siberian elm. Growth of white rabbitbrush was moderately affected. Average height of all species three, four, and five growing seasons after planting is shown in figure 5.

Only 38% of unrooted oldman wormwood cuttings were alive by fall the year of planting, while 86% of rooted cuttings survived the summer. The difference is primarily attributable to browsing by Richardson's ground squirrels (*Spermophilus richardsonii*) which are active from April until early August, the major portion of the growing season. Wire cages, 46 cm long and 10 cm in diameter, were placed around individual oldman plants in late July the year they were planted, when it was discovered how palatable herbage was to ground squirrels. Unrooted oldman cuttings apparently had insufficient reserves to withstand repeated browsing while simultaneously establishing a root system. Foliage within the cages was protected from ground squirrels, but growth protruding from the side or top of the cage was quickly eaten. The cages remained around plants that originated from unrooted cuttings throughout the study, and plant height was similar to cage height each fall (fig. 5).

The row containing rooted oldman wormwood cuttings was fenced in June 1978 to exclude Richardson's ground squirrels to permit determining the growth potential of oldman at the study site. Fencing had a 6-mm-square mesh, and extended 41 cm above the soil surface and 10 cm below the surface; a lip of wire extended outward from the bottom of the fence 10 cm to discourage ground squirrels from burrowing directly under the fence. Two electrified wires, spaced 5 cm apart, were placed above the fence. Fencing was moderately successful the summer of installation, and oldman increased to an average height of 69 cm from 41 cm the previous summer when plants were protected by wire cages. A sufficient number of squirrels burrowed under the fence the following summer to heavily browse plants and reduce height to 23 cm and to 13 cm the following year (fig. 5). The cumulative effects of heavy browsing by Richardson's ground squirrels

Table 2.—Number of individuals of each species that were planted and survival percentages at the end of each summer and year subsequent to planting

Group / Species	Number planted			Survival: First year		Second year		Third year		Fourth year		Fifth year	
	1975	1976	Total	Summer	Year	Summer	Year	Summer	Year	Summer	Year	Summer	Year
Conifer													
Blue spruce	25	10	35	100	100	97	94	94	94	94	94	94	94
Ponderosa pine	40	15	55	82	78	76	75	75	75	73	73	73	73
White fir	41	10	51	100	90	86	84	84	84	84	84	84	84
Deciduous													
Russian olive	51	10	61	89	39	33	16	16	16	16	16	16	16
Siberian elm	34	0	34	82	76	74	71	71	71	71	71	71	65
Siberian peashrub	101	11	112	76	76	62	55	54	54	54	54	54	54
Rangeland shrub													
Basin big sagebrush													
Colorado source	0	56	56	41	38	36	32	32	27	21	11	11	11
Nevada source	0	56	56	50	38	38	38	38	30	27	25	25	25
Oldman wormwood													
Rooted cutting	0	56	56	86	84	84	84	84	84	80	79	50	32
Unrooted cutting	0	56	56	38	32	32	32	32	32	32	32	32	32
White rabbitbrush	0	112	112	23	20	20	20	20	20	20	20	20	20

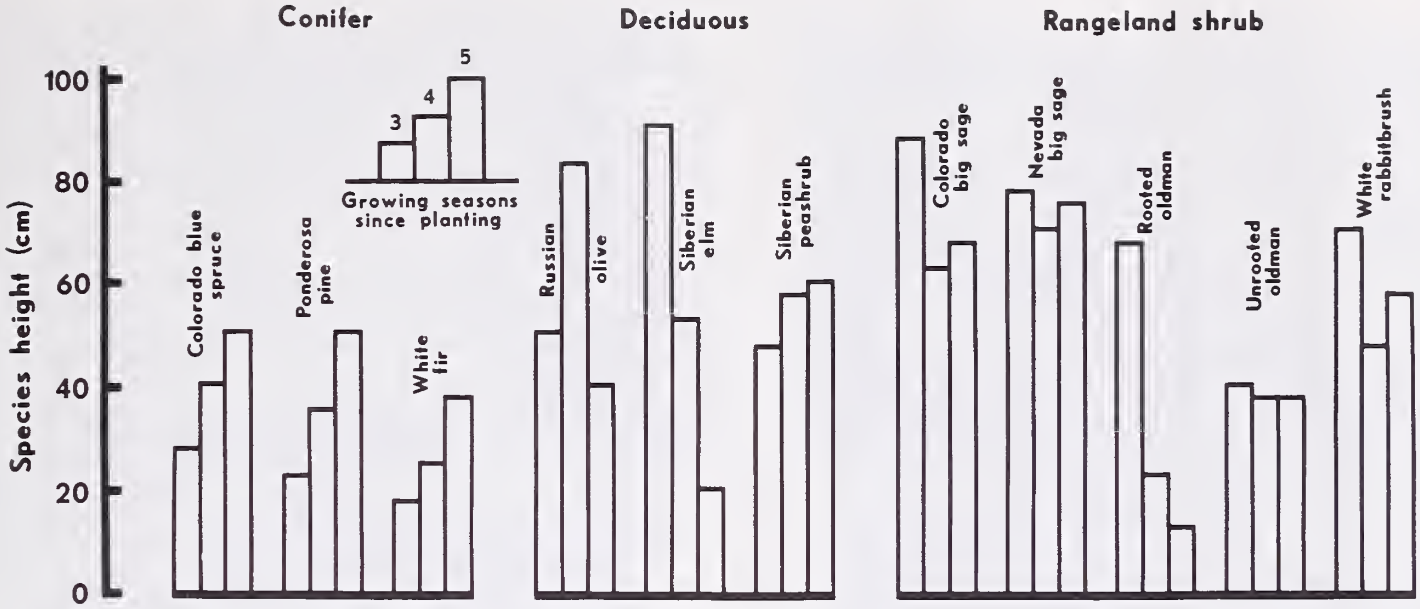

Figure 5.—Average height of species at the end of the third, fourth, and fifth growing seasons after planting.

reduced survival from 84% to 32% between the third and fifth year after planting.

Richardson's ground squirrels browsed white rabbitbrush in the summer and its stems and branches were also clipped in the winter by white-tailed jack rabbits, but this use did not cause any mortality. However, Siberian elms were severely damaged by jack rabbits during the winter. Rabbits clipped twigs within reach and debarked the trunk, thus girdling the tree and killing top growth. Elms decreased in height after the third growing season because of the depredation. All elms at the study site had a prostrate growth from 5 years after planting, and they will not become trees unless protected from jack rabbits.

The sharp decrease in height of Russian olive the fifth growing season (fig. 5) illustrates that shelterbelts are subject to man-induced calamities as well as those from climatic or biological sources. Thistles growing along a county road a short distance upwind from the study site were sprayed with 2,4-D in June 1979. Sufficient herbicide drifted across the study site to kill the tops of all Russian olives. Plants resprouted later in the summer, but by fall average height was only about half that of the preceding year. Rabbitbrush was also damaged by herbicide drift.

Observations About Individual Species

Colorado blue spruce (fig. 6). — The terminal buds of spruce were damaged more severely than other conifers the winter after planting, probably from wind-induced desiccation. A short wooden shield was placed on the windward side of each spruce prior to the second winter. Some plants were damaged in subsequent years after trees extended above the shield, but damage was not as extensive as the winter after planting. Mean height was 51 cm at the close of study, with a maximum height of 81 cm.

Ponderosa pine (fig. 7). — The growth rate of pine increased each year, and average height equaled that of spruce at the close of study. The leaders of many pines developed a distinct crook in 1979, caused by 2,4-D which drifted across the planting site when roadside weeds were sprayed.

White fir (fig. 8). — The initial rate of height growth was the slowest of any conifer, but increased to 13 cm the fifth growing season, about the same as for other conifers. Plants were slow in recovering from damage to the terminal bud suffered the winter after planting and are developing a bushy growth form.

Russian olive (fig. 9). — Mortality was confined to the first 2 years following planting, but was the highest of any traditional shelterbelt species. Those plants that did survive grew rapidly and were 84 cm tall after four growing seasons. During the following year, the tops of plants were killed by 2,4-D drift, and average height decreased about 50%. The lateral crown spread of Russian olive was about equal to plant height, so that this shrub forms an effective barrier to trap drifting snow.

Siberian elm (fig. 10). — Elms established quickly and averaged 91 cm in height three growing seasons after planting with a maximum height of 183 cm. Height progressively decreased in subsequent years because of jack rabbit depredation during the winter. No elm regained a tree-like form once the trunk was girdled, and it is doubtful this species can survive at the study site because of the severity of jack rabbit depredation.

Siberian peashrub (fig. 11). — Peashrubs were 48 cm tall three growing seasons after planting, but little additional height growth occurred the following 2 years. Individual plants remained spindly, and this species would require close spacing to form an effective wind barrier at the study site.

Basin big sagebrush (fig. 12). — Basin big sagebrush established quickly and the Colorado and Nevada selections were 69 cm and 58 cm tall, respectively, at the end of the second growing season. Neither selection was physiologically adapted to the harsh, windy environment at the planting site. Mortality occurred throughout the study and was particularly heavy after the severe 1978-1979 and 1979-1980 winters.

Oldman wormwood (fig. 13). — The extremely palatable nature of oldman wormwood foliage to Richardson's ground squirrels prohibits its use at locations where this species of ground squirrel is present. The row containing oldman cuttings initially rooted was fenced to exclude Richardson's ground squirrels before the third growing season and plants were 69 cm tall by fall. Squirrels tunneled under the fence the next summer and height decreased to 23 cm. Continued heavy browsing in subsequent years reduced plant vigor to such a low state that 47% of the original population of rooted oldman died the fifth year after planting.

White rabbitbrush (fig. 14). — White rabbitbrush was the only rangeland species to show promise for use in a shelterbelt planting. It was browsed by Richardson's ground squirrels in summer and white-tailed jack rabbits in winter, though not heavily enough to produce mortality. Plants grew rapidly and averaged 61 cm in height at the end of the second growing season. They fluctuated around this height for the remainder of the study. Only 20% of plants survived 1 year after planting, but there was no additional mortality. Additional field trials are needed to improve establishment methods before this species can be recommended for shelterbelt use.

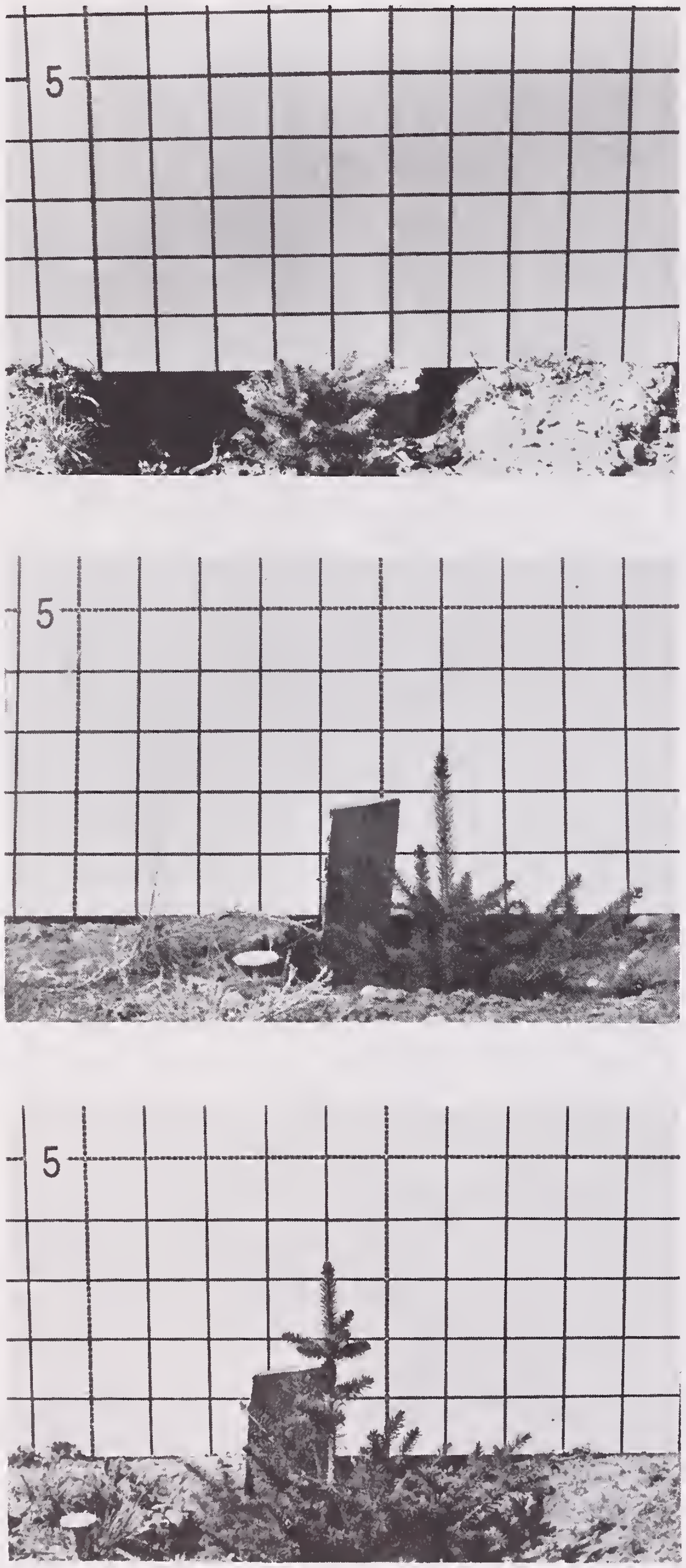

Figure 6.—Growth form of a Colorado blue spruce three (top), four (middle), and five (bottom) growing seasons after planting. The grid is composed of 1-dm squares.

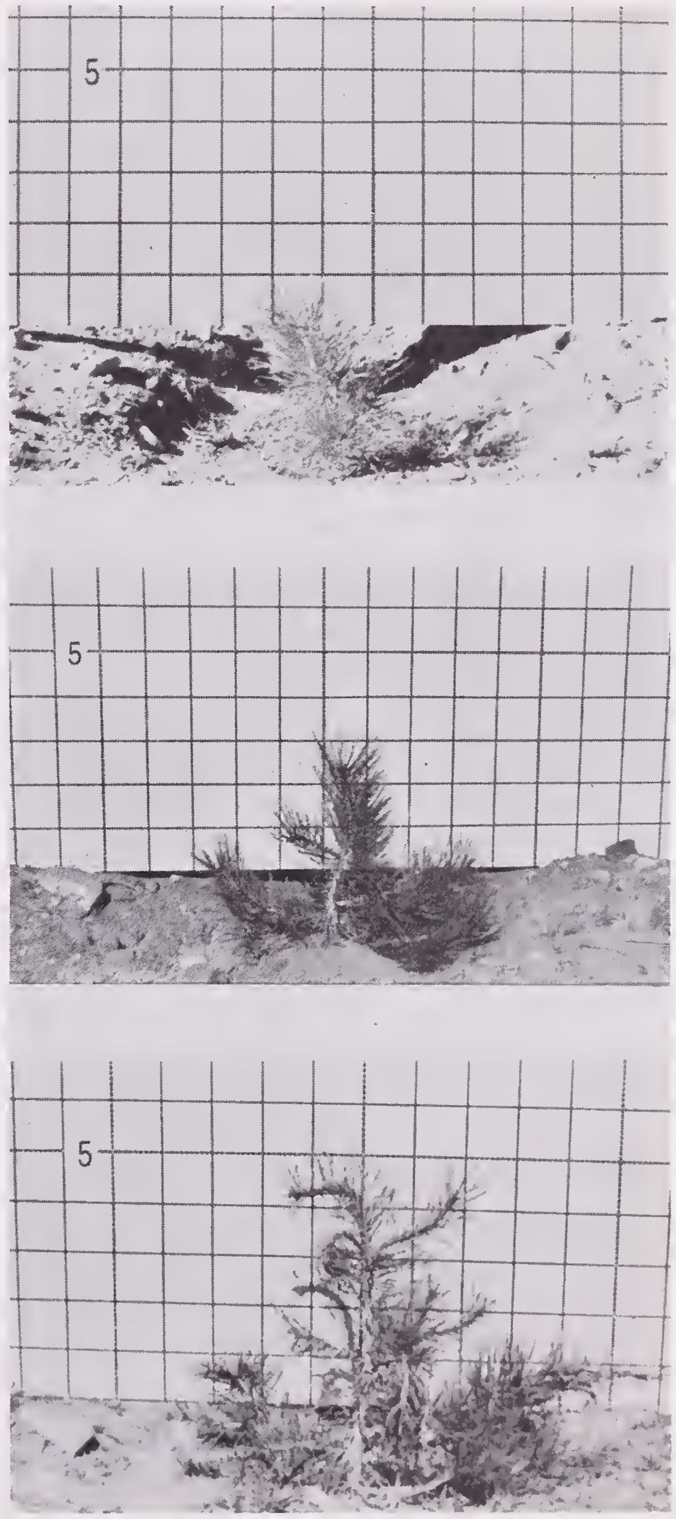

Figure 7.—Growth form of a ponderosa pine three (top), four (middle), and five (bottom) growing seasons after planting. Contorted leader growth in bottom photo was caused by 2,4-D which drifted across the study site when roadside weeds were sprayed. The grid is composed of 1-dm squares.

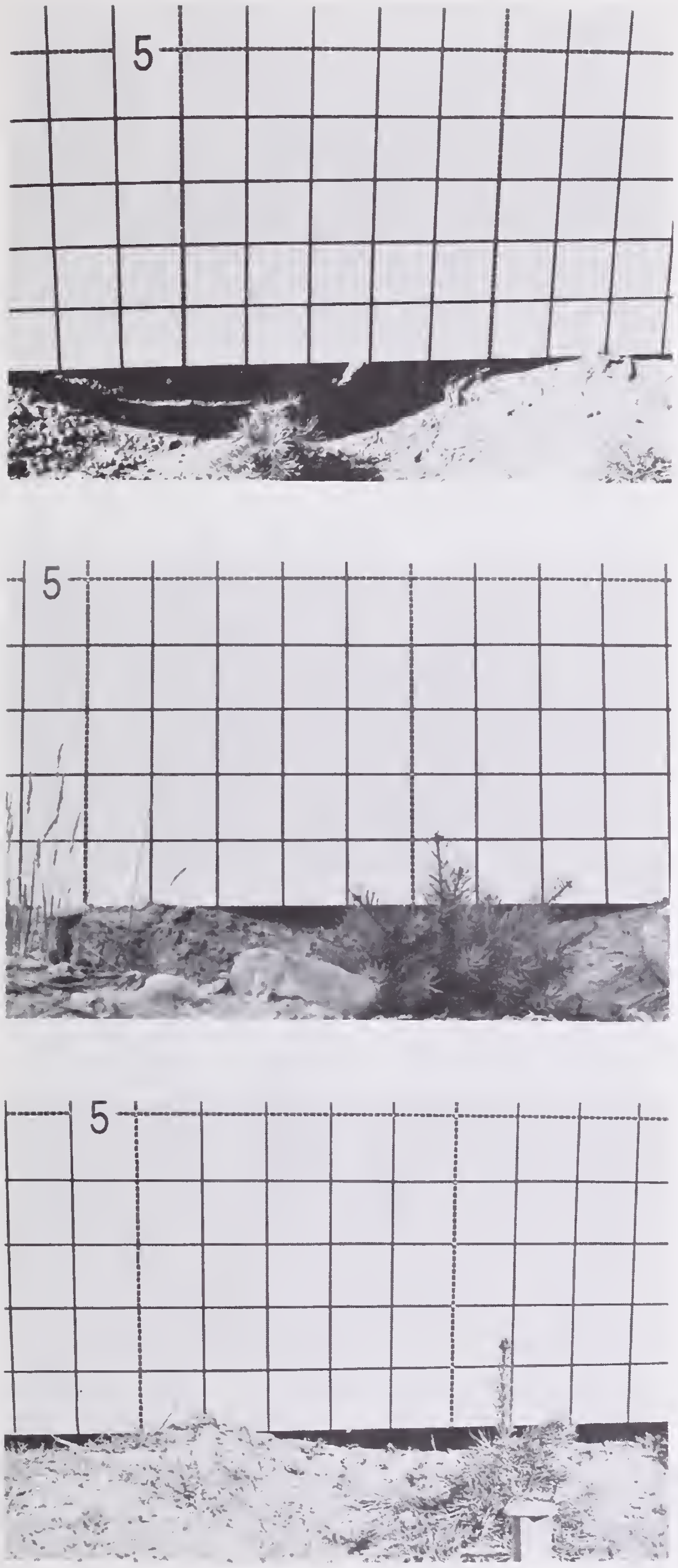

Figure 8.—Growth form of a white fir three (top), four (middle), and five (bottom) growing seasons after planting. The grid is composed of 1-dm squares.

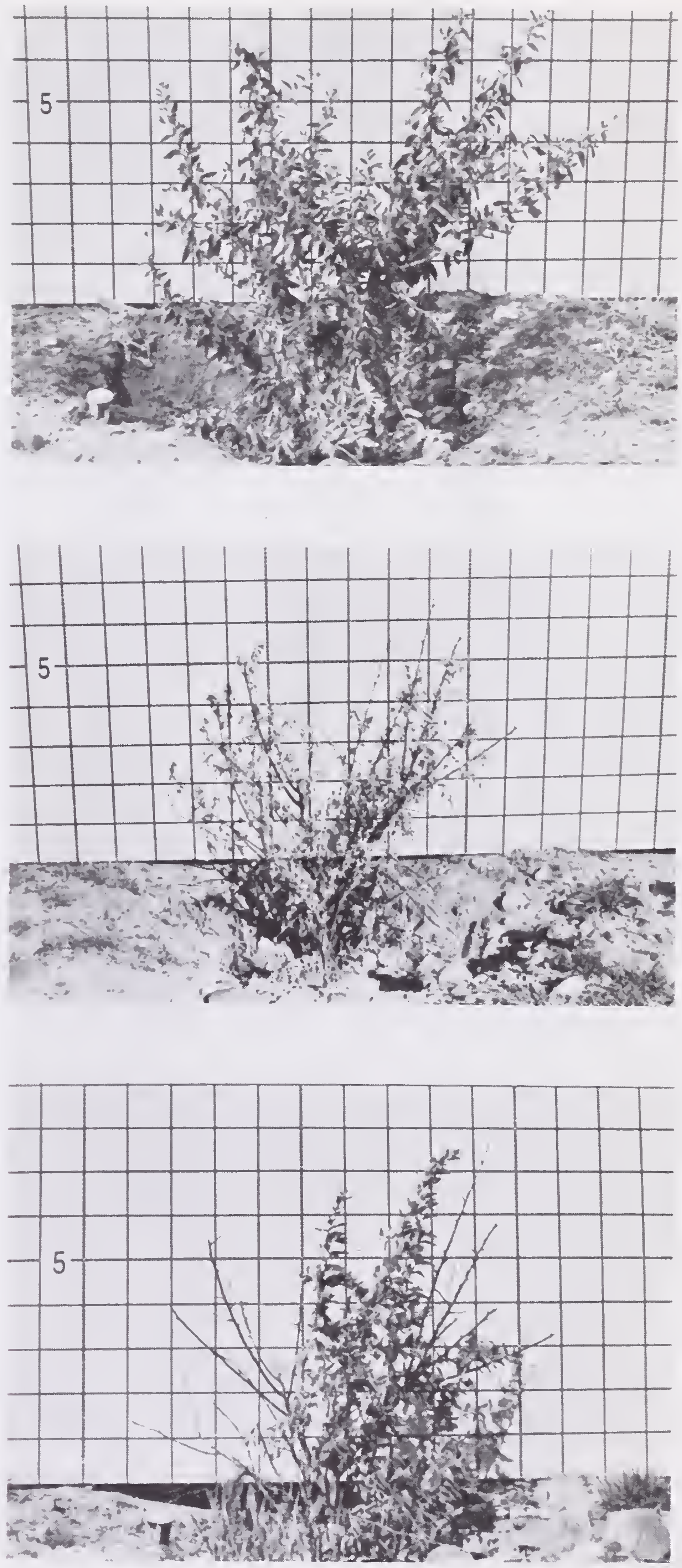

Figure 9.—Growth form of a Russian olive three (top), four (middle), and five (bottom) growing seasons after planting, Top growth was killed (bottom photo) by 2,4-D drift, but plants resprouted from the trunk later in the summer. The grid is composed of 1-dm squares.

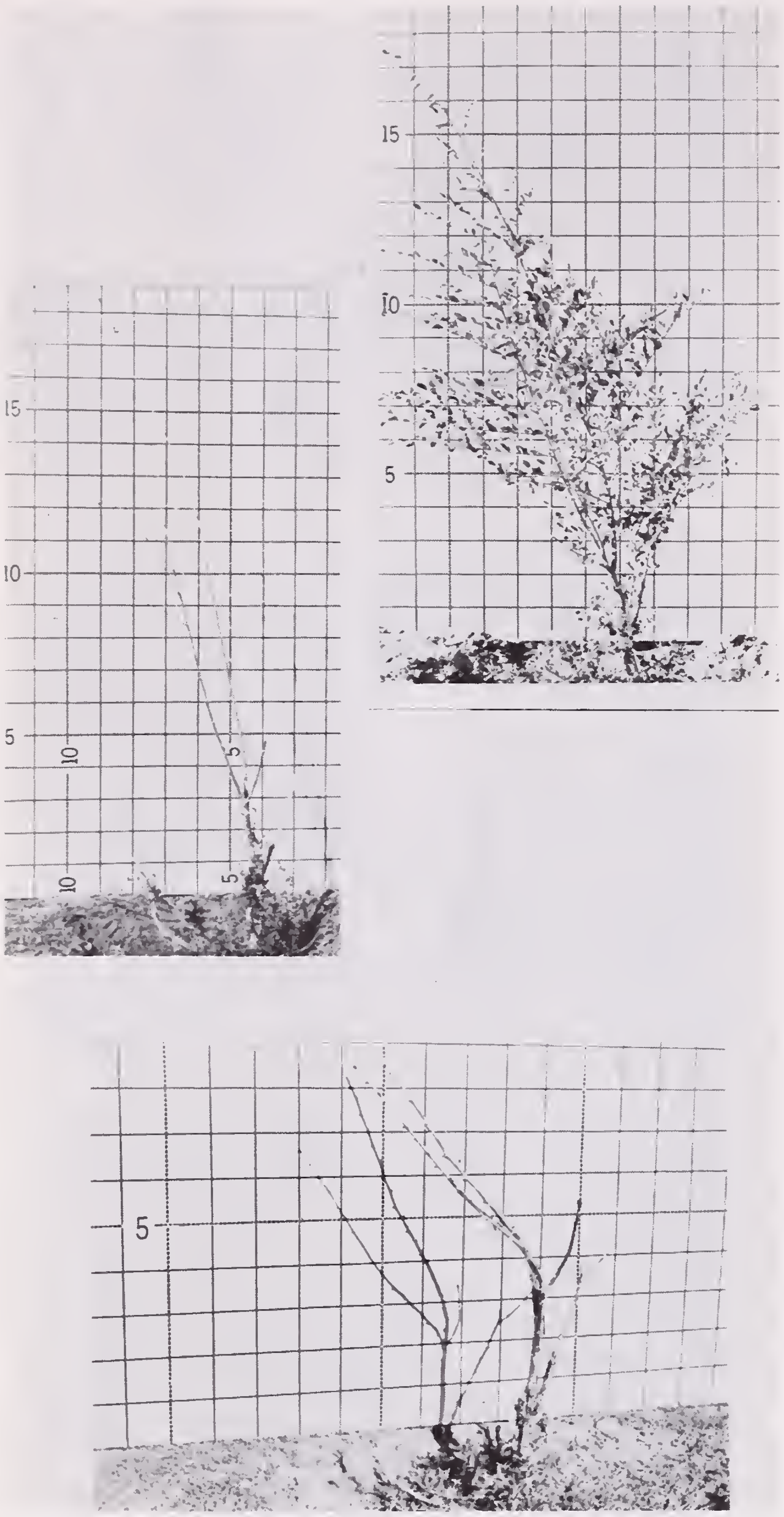

Figure 10.—Growth form of a Siberian elm three (top), four (middle), and five (bottom) growing seasons after planting. Jack rabbits girdled the trunk and browsed on twigs during winter months. The grid is composed of 1-dm squares.

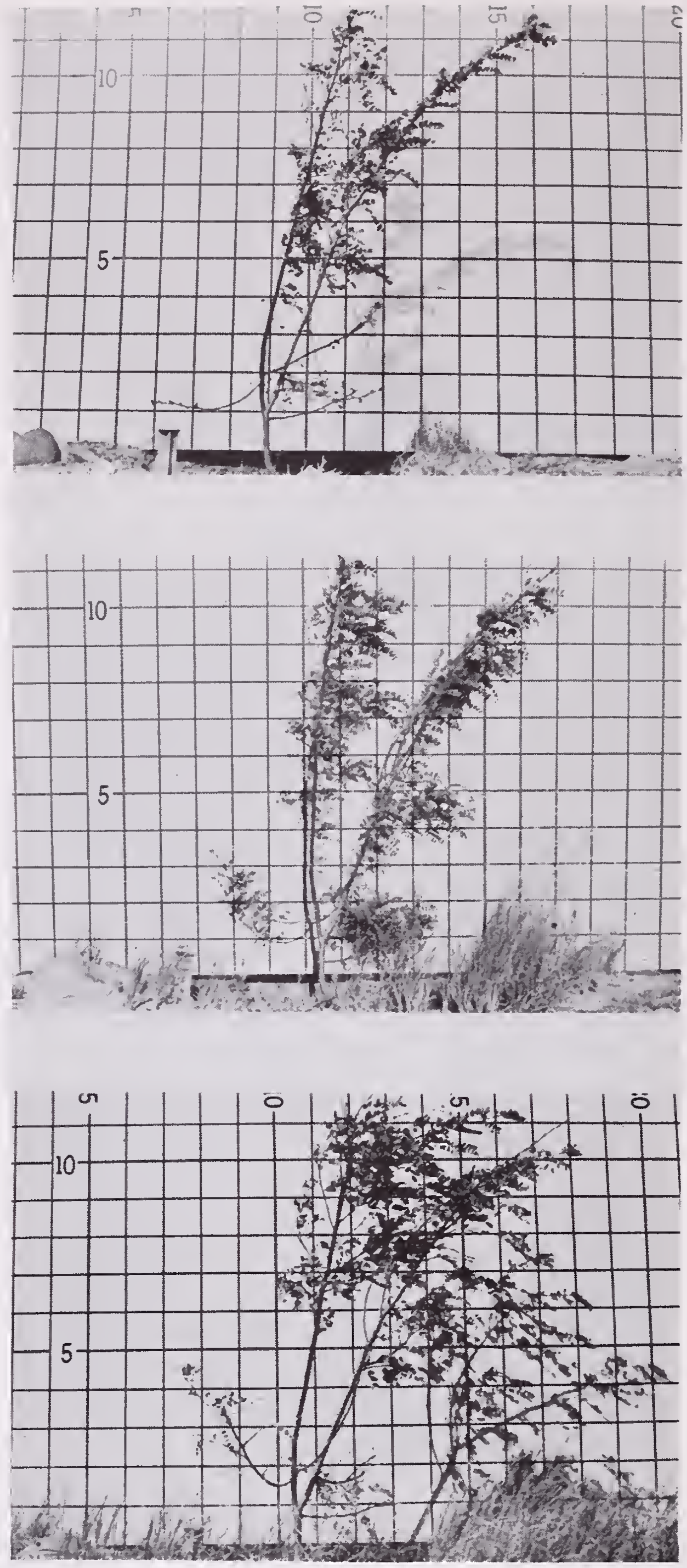

Figure 11.—Growth form of a Siberian peashrub three (top), four (middle), and five (bottom) growing seasons after planting. The grid is composed of 1-dm squares.

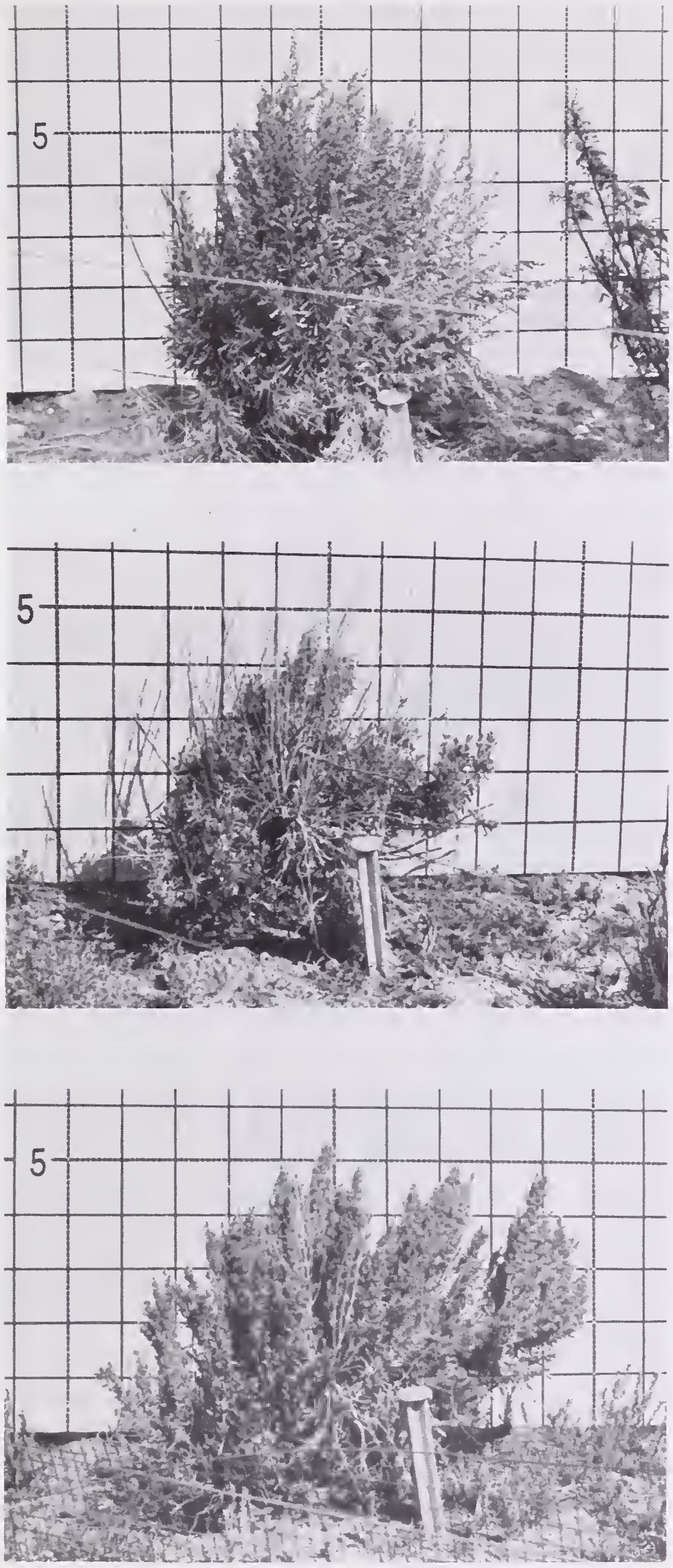

Figure 12.—Growth form of a basin big sagebrush from Colorado three (top), four (middle), and five (bottom) growing seasons after planting. The selections from both Colorado and Nevada winter-killed through the study. The grid is composed of 1-dm squares.

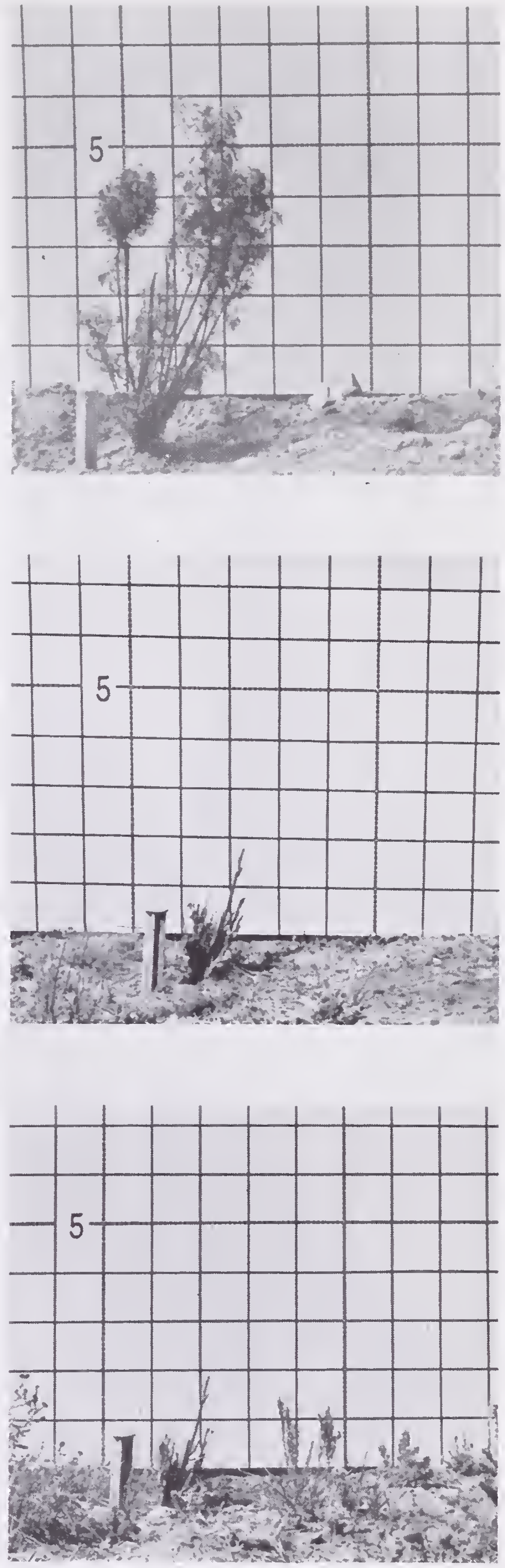

Figure 13.—Growth form of an oldman wormwood planted as a rooted cutting three (top), four (middle), and five (bottom) growing seasons after planting. The row was fenced to exclude Richardson's ground squirrels at the beginning of the third growing season, but depredation in the following two years was still severe. The grid is composed of 1-dm squares.

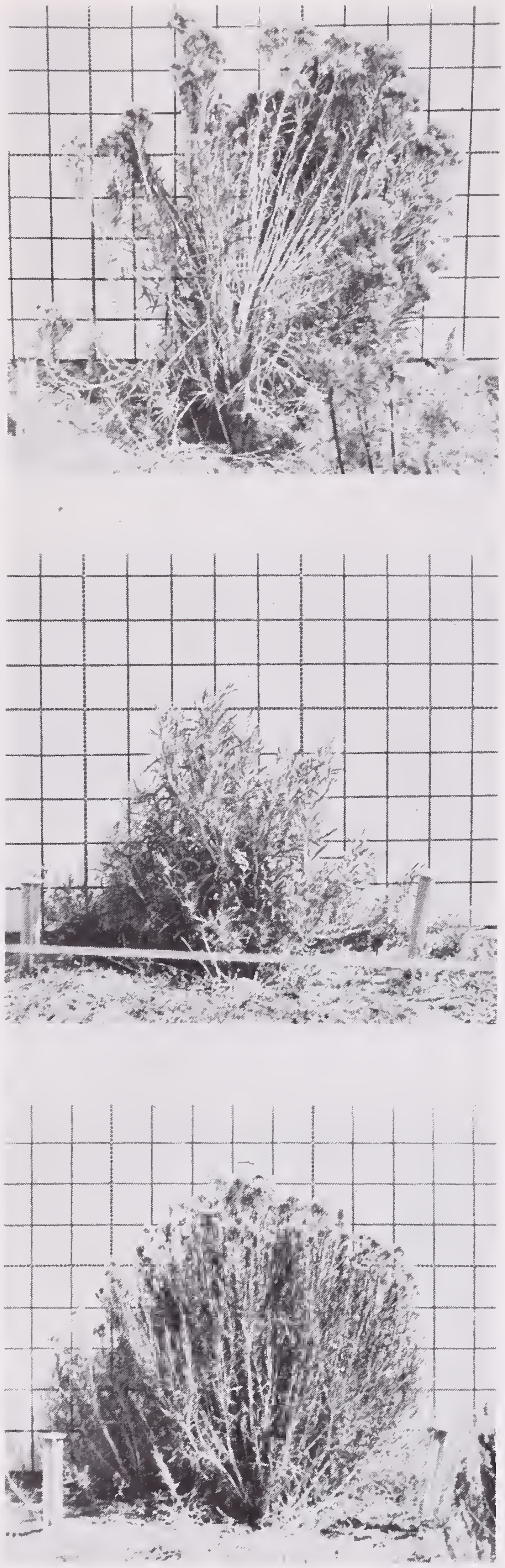

Figure 14.—Growth form of a white rabbitbrush three (top), four (middle), and five (bottom) growing seasons after planting. Rabbitbrush was moderately damaged by 2,4-D drift (middle photo). The grid is composed of 1-dm squares.

Literature Cited

Cook, Jim, 1978. Windbreaks for farm and ranch homes. Bulletin 674, 6 p. Agricultural Extension Service, Wyoming Agricultural Experiment Station, University of Wyoming, Laramie.

Edmondson, W. O. 1951. Trees for protection and profit. Circular 116, 41 p. Agricultural Extension Service, Wyoming Agricultural Experiment Station, University of Wyoming, Laramie.

Howard, Gene S. 1964. Shelterbelt tree and shrub species under dryland culture in the Central Great Plains. Production Research Report 78, 16 p. Agricultural Research Service, U.S. Department of Agriculture, Washington, D.C.

Howard, Gene S. 1982. Recommended horticultural plants generally hardy and adaptable in the Central Great Plains Region. Bulletin 770, 8 p. Wyoming Agricultural Experiment Station, University of Wyoming, Laramie.

Howard, Gene S., Frank Rauzi, and Gerald E. Schuman. 1979. Woody plant trials at six mine reclamation sites in Wyoming and Colorado. Production Research Report 177, 14 p. Science and Education Administration, U.S. Department of Agriculture, Washington, D.C.

Johnson, Kendall L. and Eugene S. Anderson, editors. 1980. Conservation planting handbook for Wyoming and Colorado. (Unpaginated). Agricultural Extension Service, Wyoming Agricultural Experiment Station, University of Wyoming, Laramie.

Plummer, A. Perry. 1974. Oldman wormwood to stabilize disturbed areas. Utah Science 35(1):26-27.

Tabler, Ronald D. 1980. Geometry and density of drifts formed by snow fences. Journal of Glaciology 26(94):405-419.

Tabler, R. D. and R. P. Furnish. 1982. Benefits and costs of snow fences on Wyoming Interstate-80. Transportation Research Record 860:13-20, National Academy of Sciences, Washington, D.C.

Sturges, David L. 1983. Shelterbelt establishment and growth at a windswept Wyoming rangeland site. USDA Forest Service Research Paper RM-243, 12 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Survival and growth of six shelterbelt tree and shrub species and three rangeland shrubs were evaluated for 5 years at a planting site adjacent to Interstate-80 in southcentral Wyoming. Depredation by rodents at the rangeland site limited establishment and growth of some species more severely than did the harsh climate.

Keywords: Shelterbelts, Wyoming, wildlife depredation

Sturges, David L. 1983. Shelterbelt establishment and growth at a windswept Wyoming rangeland site. USDA Forest Service Research Paper RM-243, 12 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Survival and growth of six shelterbelt tree and shrub species and three rangeland shrubs were evaluated for 5 years at a planting site adjacent to Interstate-80 in southcentral Wyoming. Depredation by rodents at the rangeland site limited establishment and growth of some species more severely than did the harsh climate.

Keywords: Shelterbelts, Wyoming, wildlife depredation

Sturges, David L. 1983. Shelterbelt establishment and growth at a windswept Wyoming rangeland site. USDA Forest Service Research Paper RM-243, 12 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Survival and growth of six shelterbelt tree and shrub species and three rangeland shrubs were evaluated for 5 years at a planting site adjacent to Interstate-80 in southcentral Wyoming. Depredation by rodents at the rangeland site limited establishment and growth of some species more severely than did the harsh climate.

Keywords: Shelterbelts, Wyoming, wildlife depredation

Sturges, David L. 1983. Shelterbelt establishment and growth at a windswept Wyoming rangeland site. USDA Forest Service Research Paper RM-243, 12 p. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colo.

Survival and growth of six shelterbelt tree and shrub species and three rangeland shrubs were evaluated for 5 years at a planting site adjacent to Interstate-80 in southcentral Wyoming. Depredation by rodents at the rangeland site limited establishment and growth of some species more severely than did the harsh climate.

Keywords: Shelterbelts, Wyoming, wildlife depredation

Rocky
Mountains

Southwest

Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Lubbock, Texas
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526